EXPOSURE: AN EXPERT SYSTEM FIRE CODE

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Acknowledgements

ABSTRACT

This report addresses the issue of developing an expert or knowledge-based system that deals with the problem of preventing the spread of fire between buildings. A knowledge-based program, EXPOSURE, has been developed that facilitates using more appropriate technology, expanding the problem domain, and providing cost-effective solutions. EXPOSURE can solve the problem of the prevention of the spread of fire between buildings for the case when the exposed building has combustible walls. The use of the expert system EXPOSURE and NFPA 80A produce significantly different recommended minimum separation between buildings. In some cases EXPOSURE calls for significantly greater separation and in others significantly less. In one case the separation required by NFPA 80A was more than five times greater than what EXPOSURE recommended. This program demonstrates that significant cost savings in achieving the desired level of fire safety and in assuring the levels of safety can be obtained by use of expert system fire codes.

Key Words: Artificial intelligence, expert systems, fire codes, building codes, exposure, computer programs

A. INTRODUCTION

This report is one of three that summarizes the technical accomplishments achieved on an Air Force contract titled "Fire Protection Design Assessment System." The project's objective, briefly, was to develop an expert system to determine fire safety specifications for the design of buildings. As a first step, we have selected the problem of the prevention of the spread of fire between adjacent buildings as addressed by a standard practice NFPA 80A [1]. This report describes a computer program, EXPOSURE, which is an expert system version of NFPA 80A. The other two reports deal with EXPOSURE80A (a system which requires strict compliance with NFPA 80A as opposed to an expert system) [2] and the calculation of the radiation from a fire incident on a building [3].

This paper discusses a way of improving fire safety building codes by using expert systems or knowledge-based systems. The distinction between these two types of artificially intelligent computer programs is not important in the context of this report and these terms are used interchangeably.

A.1. Importance of improving fire codes

The total expenditure on construction in the U.S. is about $400 billion. Building construction is a highly regulated business in that there are building codes for every aspect of the building [4]. Nearly half of the building codes relate to fire safety [5]. Compliance with fire safety codes that are too conservative may be unnecessarily expensive.

The Fire Safety Evaluation System (FSES) developed at the Center of Fire Research grew into NFPA 101M, Alternative Approaches to Life Safety [6]. Estimates of savings from this improved approach are hard to obtain, but there is anecdotal evidence indicating savings of millions of dollars. Some estimates of the total savings run into billions of dollars [7] [8]. Expert system will enable the incorporation of additional and perhaps more appropriate technology into the fire codes providing additional economies.

Direct fire losses in the United States in 1988 were estimated as 6215 deaths, 30,800 injuries, and direct property loss of about $8.35 billion [9]. These figures do not include cost of fire protection in construction, fire insurance, and operating fire departments. If a means was provided to:
   a. make the technological base for fire codes stronger,
   b. reduce the arbitrariness in the applications of fire codes,
   c. reduce over and under design for safety, and
   d. make the process of applying or checking a building's compliance with fire codes more manageable,

the cost of fire protection and losses could be significantly cut, perhaps by several billion dollars annually.

A.2. Shortcomings of fire codes

While fire safety building codes are the keystone of fire safety, they have serious shortcomings [10] [11]. Some of their major problems are:
1. They are hard to interpret, understand, and/or apply;
2. They do not cover all applications; and
3. They require a substantial understanding of fire codes and fire protection engineering to bring a building into full compliance.

The main users of fire codes include architects, building owners, code officials, and fire protection professionals. Some of these users do not have familiarity with the codes to comply efficiently and accurately with them. The innovative design of some buildings requires the application of state-of-the-art technology to demonstrate their level of fire safety. Fire science and fire protection engineering are highly complex and sometimes empirical technologies. The correct application of the most appropriate technology is challenging even for many fire protection professionals so it is clearly often difficult for the other users.

Many aspects of building design are being automated. It is inevitable that some computerized form of fire codes will come into widespread use [4]. Because of the complexity of the problem and the need to deal with exact and inexact knowledge, one promising form for this automation to take is that of an expert system [11] [12].

A.3. Overview of this report

The particular fire code selected for this project is the one that deals with the prevention of the spread of fire from a burning structure to a neighboring structure. In the past major conflagration have often resulted when fires have spread to neighboring buildings. The potential for fire spread to a neighboring building is, therefore, of primary concern when evaluating the fire safety of any building. Also, after rescuing people from a burning building, a fire department's top priority is to stop the spread of the fire to adjacent structures [13].

EXPOSURE addresses the same basic problem as NFPA 80A but expands the class of users to include non-fire safety professionals. This is a major shift in skill level required by the user from fire protection professional to non-professional. EXPOSURE also

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incorporates more appropriate technology and has a greater degree of flexibility because it takes more advantage of the computational capability of a computer.

The next section will describe the background of the exposure problem and NFPA 80A. This leads to the description of the initial expert system version of this fire code, EXPOSURE. Finally, the results of applying NFPA 80A and EXPOSURE to the same buildings are compared and the implications of this work for the development of automated fire codes are discussed.

B. Background for the Exposure Problem and NFPA 80A

The spread of fire from a burning building to a neighboring building has been discussed in the literature [14] [15] [16] [17]. Therefore, the technical problem and its solution will only be summarized.

The exposure problem can be described as the prevention of the energy from the fire of one building from doing damage to an adjoining building. Conventional wisdom, based on general observation of fires, is that the most common mechanisms for damage are radiation and direct contact with the flames. To analyze the problem, the strength of the fire in the burning building as a function of time, the extent of the flames, the radiation falling on the exposed building, and the damage mechanism of the exposed surfaces need to be known. Solutions to the exposure problem will deal with these points either explicitly or implicitly.

As its title indicates NFPA 80A: Recommended Practice for Protection of Buildings from Exterior Fire Exposures [1] is a recommended practice. The basic problem it addresses involves two buildings. The burning building is called the exposing building, while the other which is threatened is called the exposed building. To do the complete exposure problem one has to assume first one and then the other building is the exposing building.

A key concept needed to use 80A is that of a fire containment compartment. A fire containment compartment can be defined as a region of a burning building that has physical surfaces that enclose and will contain any fire expected to occur within it. If one of these surfaces is an exterior wall, that surface need not contain the fire. The extreme limit in size for a fire containment compartment is the entire building. However, normally a complex building will have a number of fire containment compartments. In order to comply with NFPA 80A, a fire in any compartment of the burning building must not spread to the adjoining building.

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The universe of problems to which 80A is applicable is to a major extent defined by the explicit or implicit assumptions made for 80A. A few of the key ones for NFPA 80A are:

1. All combustible materials have a piloted ignition threshold equal to that of oven dried wood, i.e., 0.3 cal./sq. cm./sec. or 66 Btu./sq. ft./min.

2. The exposed and exposing walls are parallel.

3. Openings are assumed to be uniformly distributed over the exposing wall and the separation between openings will be no more than one-third of the separation between the two buildings.

4. Only buildings with walls capable of fitting into the following categories are considered:
        a) frame or combustible,
        b) fire-resistive wall (3-hour minimum),
        c) veneered wall (combustible construction covered by a
           minimum of four inches of masonry), or
        d) non-combustible (fire resistance less than 3 hours).
In addition, one must be able to determine if the walls can contain the fire
        a) less than 20 minutes,
        b) 20 minutes or more, but less than the duration of the
           fire, or
        c) the duration of the fire.

5. All fires can be classified as one of three severities, light, moderate, and severe, by using either the average combustible load per unit area or the average flame spread rating for interior flame spread.

6. All doors, windows, and other openings of a building transmit without attenuation the radiation of the fire within it.

The underlying physics of 80A is that the burning building radiates through the openings in the exposing wall as a blackbody. The severity determines the temperature of this blackbody and thereby the strength of this source of radiation flux. The required minimum separation is the distance for which the maximum radiation falling on the exposed wall is just 0.3 cal./sq. cm./sec.

C. Description of EXPOSURE

EXPOSURE was developed on a Symbolics computer and has been

written in Symbolics Common Lisp, Flavors, and Joshua[1]. In particular, significant use has been made of Symbolics graphics, windowing, and menu facilities.

The following will describe:
1. the appearance of EXPOSURE to the user in a typical application,
2. the underlining assumptions and technological base in comparison to those of 80A, and
3. the general structure of the program.

The program assumes its user has identified two buildings, at least one of which may cause a fire in the other and he has their floor plans and their relative location. The user will be expected to read the requested information off these plans and enter them into this program.

C.1. Appearance of EXPOSURE

At the start of the program the introduction screen, Figure 1, introduces the user to the system by giving the purpose, credit to the sponsor, author, and identifies the fire protection engineer expert. Upon touching any key, the second screen, Figure 2, appears and explains how to operate the mouse and gives instructions on how to proceed. The "Tutor" and "Help" options have not been implemented. If the mouse is clicked on "Start" then the screen appears as shown in Figure 3. The user must enter his name. The system allows him to proceed only if his name has been entered as one who can operate the system. Assuming the user is authorized to continue, then the screen configuration shown in Figure 4 appears. This is the beginning of the graphic editor and the menu system for entering information on the two buildings. The user has the option of recalling an existing file for editing or of creating a new configuration.

Figures 5, 6, 7, 8, and 9 depict various menus and views of the building as the information is being entered or edited. Figure 5 shows the selection of an already existing file to be loaded. Figure 6 shows the top view of two buildings of the exposure problem with the reference bench mark shown as an x with a circle around it. To add a building, the user clicks on the command "Add Building" in the lower window and a menu appears as shown in Figure 7. If instead of adding a building, one wishes to change a

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[1] Note: Certain commercial products are identified in this report in order to adequately specify the computer programs. Such identification does not imply recommendation by the National Institute of Standards and Technology, nor does it imply that these products identified are necessarily the best available for the purpose.

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building's configuration or specifications the user clicks on the appropriate command and a menu as shown in Figure 8 appears.

Figures 9, 10, 11, and 12 display various input menus relating to entering information on the walls and openings. Figure 9 shows the exposing wall with the four windows uniformly spaced. Figure 10 shows the same wall with the menu for editing this wall. Figure 11 depicts the menu for the addition of a new opening in a wall. Finally, Figure 12 shows the menu for editing the properties of an opening in the wall.

If the user cycles through all the walls, eventually the screen appears again as in Figure 6. When he has finished entering information about the buildings, the user clicks on "analyze," as shown in Figure 6. The screen as shown in Figure 13 then appears. If the user clicks the mouse on "Start", which is found near the top of the screen, after a few minutes the screen as shown in Figure 14 appears. In this time the program does the required computations and finally suggests several solutions based upon a rough cost estimation of each solution.

C.2. Basic Assumptions

In general, it is impossible to find an acceptable solution to every exposure problem for a pair of buildings. An acceptable answer is normally one that is not too expensive to implement. Therefore, the domain addressed must be limited to one in which solutions can be found that will prevent the spread of fire in all reasonable situations and that are consistent with an acceptable level of risk or cost. In addition, some assumptions are made to simplify the problem domain initially addressed. If the program is developed further, some of these will be modified or dropped. These assumptions are:

    1. The fire department will be actively fighting the fire no later than 20 minutes after ignition. It is assumed that the fire fighters will control the spread of fire caused by flying brands.

    2. Piloted ignition is the method of fire propagation between buildings when the element ignited is on the exterior of the building.

    3. Weather conditions such as wind are ignored.

    4. Buildings are one story high with flat roofs.

    5. Only two buildings at one time are considered.

    6. All interior walls are discounted; each building thus has one fire compartment.

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7. All buildings burn at a maximum constant temperature for 3 hours.

8. No flames are outside the openings of the exposing wall.

9. All buildings are rectangular in shape.

10. The exposing and exposed walls are parallel (This is required because of the program's interface. The radiation calculation portion can deal with nonparallel walls).

11. Only wall-to-wall exposure is considered. No wall-to-roof or roof-to-wall. Therefore, any flames coming out of the roof of the exposing building are neglected.

12. The only openings allowed are windows and doors.

13. All the windows and doors with a rating of less than 3 hrs. become open at flashover.

C.3. Major Steps in EXPOSURE

EXPOSURE executes four major steps in obtaining a solution of the exposure problem: (1) identify the problems, (2) find reliable solutions, (3) estimate the relative costs of the solutions, and (4) provide for the user to select solutions.

Presently the first major step has been implemented for a combustible exterior wall, the second step has been implemented for failures only and only a few solution types, the third and fourth steps have not been implemented.

Let us now go back over these major steps giving additional details.

Major Step 1: Identify the Problems

Three classifications to describe the damage done through exposure have been arbitrarily created: no damage, failure, and hazard. The no damage classification is clear. A failure indicates a reasonable possibility of fire spreading from one building to another. A hazard indicates some minor fire damage or the ignition of a small part of the exposed building. If it is ignition, it is at a level that may not ignite a major portion of the building. Either the program or the user must identify unacceptable hazards. Only failure of a combustible wall has been implemented.

We may divide this major step into a series of substeps.

Substep 1. Determine which walls are exposing which walls. This requires the user to identify these walls.

Substep 2. Determine the strength of the source of radiation. Our analysis shows that NFPA 80A severity levels of light, moderate, and severe corresponds to the radiation emitted by an ideal black body at temperatures of 1102, 1311, and 1559 K respectively. For EXPOSURE an analytical expression for the maximum temperature under natural draft conditions was used. The equation is

$$T = 290 + DT \ (5/9)$$

where DT is the maximum temperature rise in Fahrenheit. Law [15] gives the following expression for DT:

$$DT = 8025 \ (1 - \exp(-.18n))(1 - \exp(-.25u))/n^{.5}$$

where

$n = At/X$

$X = \sum_{i=1}^{m} Awi \ (hi)^{.5}$

m is the number of windows

hi is the height of the ith window in ft.

Awi is the area of the ith window in sq. ft.

$u = L/(Aw \ At)^{.5}$

$At = 2Af + 2H(D + W) - Aw$

Af = floor area in sq. ft.

Aw = total window area in sq. ft.

L = fire load in lbs./sq. ft.

H = height of compartment in ft.

D = depth of compartment in ft.

W = width of compartment in ft.

Substep 3. Determine the configuration factor for the exposing and exposed walls. The guide number table of NFPA 80A rests upon the calculation of the configuration factor for the case of parallel walls and a uniform distribution of openings. EXPOSURE has the ability to compute the maximum configuration factor on

the exposed wall due to any placement of rectangular openings in the exposing wall. These walls need not be parallel.

Substep 4. Identify subregions of the exposed wall with problems and the nature of the problem. Presently EXPOSURE assumes the entire exposed wall is one subregion of combustible material. If the radiation falling upon the wall exceeds the piloted ignition threshold of the combustible material, the system recognizes a failure and looks for solutions.

Major Step 2: Find Reliable Solution.

A solution is a set of actions that eliminates all the failures and unacceptable hazards. These actions must not create new failures or unacceptable hazards.

The only types of solutions that have been implemented are:
1. increase the separation,
2. change the combustible material to one having a higher piloted ignition threshold, and
3. add an exterior automatic water curtain on the exposed building.
In addition, a very simplistic cost estimator is included for illustration.

Major steps 3 and 4, which have not been implemented, were planned to allow the accurate estimation of the relative costs of the solutions and provide for the user to select a solution. The solutions would have been prioritized based upon their estimated relative cost. Also, whenever the system proposed a solution, the user would have been given the following options for each solution:
1. acceptance of the proposed solution,
2. acceptance of the proposed solution and request additional protection, or
3. rejection of the proposed solution.

D. Comparisons between NFPA 80A and EXPOSURE

The buildings used to compare NFPA 80A and EXPOSURE are shown in Figure 6. One of the buildings, bldg-a, has no openings in the wall facing the other building, bldg-b. Figure 6 shows these two buildings with bldg-a at the top of the screen. Bldg-b's exterior walls are 3-hour fire walls. The wall of bldg-b facing bldg-a has at least one opening. Three different cases of exterior wall material for bldg-a: plain wood, wood covered with a thin layer of combustible material, and a non-wood combustible material are considered. The piloted ignition threshold for these surfaces were taken to be 1.255, 1.75, and 2.5 w/sq cm. Bldg-b

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will be assumed to have three-quarter hour rated windows which are protected by a deluge exterior automatic water curtain. Two window patterns are assumed: 1. uniform (i.e., four uniformly spaced windows, each 7.5 ft. wide and 16.67 ft. high as shown in Figure 9) and 2. one big opening 30 ft. wide and 16.67 ft. high in the middle of the exposing wall. In both cases the total area of the openings was 500 sq. ft. The heights of the buildings were taken to be 20 ft.

Tables 1, 2,and 3 show the results of applying NFPA 80A and EXPOSURE to buildings with various siding material, depth of the exposing building, and fire load. In Table 1 the exposing building, bldg-b, is 100 ft. square and the fire load of 50 lbs./sq. ft. was taken so there was a severe fire according to NFPA 80A. For Table 2 the exposing building depth (the dimension perpendicular to the exposing wall) was reduced to 10 ft. Note that in all cases NFPA 80A gave the same minimum separation of 60 feet. However, EXPOSURE gave minimum separations ranging from a low of 11 feet to a high of 56 feet. The values for the minimum separation for NFPA 80A has an additional 5 feet safety margin built into it. So to compare the minimum separations one should add 5 to the EXPOSURE results. For Table 3. the exposing building is restored to 100 feet square, but the fire load density is reduced to 6.9 lbs./sq. ft. While in Tables 1 and 2 EXPOSURE gave smaller values for the minimum separation, in Table 3 we see EXPOSURE gives significantly larger values.

If it is true as we have asserted that NFPA 80A and EXPOSURE rest upon the same basic physics how do we explain this seemingly total lack of agreement? There are three principle sources that could cause this disagreement: source temperature, configuration factor, and ignition criteria. Each of these will be dealt with in turn.

First, regarding the ignition criteria, NFPA 80A and EXPOSURE use the same criteria only for plain wood since EXPOSURE uses the actual piloted ignition threshold for the exposed materials while NFPA 80A uses the piloted ignition threshold for wood for all combustibles. Therefore, only the plain wood cases should be considered when trying to see the agreement because of the same basic physics.

Another part of the explanation of why the results of NFPA 80A and EXPOSURE differ by so much is due to the estimation of the temperature of the source. NFPA 80A used just three temperatures for the source each corresponding to a severity classification based only on the properties of average fire load and average flame spread rating. These temperatures are estimated by the author to be 829 C (1524 F) for the light classification, 1038 C (1900 F) for moderate, and 1286 C (2347 F) for severe. The average flame spread rating is assumed to be in the range 0 to 25. This would result in a light severity classification based on

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this property. Then the load per sq. ft., would determine the
severity classification of the building. Therefore, a fire load
of 0 to 7 lbs./sq. ft. would result in a light classification. If
an ambient temperature of 17 C (62.6 F) is assumed then it
follows from the above that:

   a light classification corresponds to a temperature rise
   of 812 C (1494 F);

   a moderate classification (a fire load of 7 to 15 lbs./sq.
   ft.) corresponds to a temperature rise of 1021 C (1870 F);
   and

   a severe classification (a fire load of 15 lbs./sq. ft. or
   greater) corresponds to an estimated temperature rise of
   1269 C (2316 F).

EXPOSURE uses the analytical expression previously given (see
page 8) to estimate the increase of the burning building's
temperature. The behavior of this analytical expression can be
seen in Figures 15, 16, and 17. For Figure 15 there are two
curves. One for a building with 500 sq. ft. of windows and
another with 1000 sq. ft. In Figure 15, it is apparent that the
temperature rise of 812 C (1494 F) for a fire load of 0 to 7
lbs./sq. ft. underestimates the temperature significantly in the
upper portion of the fire load range. In the 7 to 15 lbs./sq. ft.
range the temperature rise of 1021 C (1870 F) is significantly
low for both cases considered. Finally the temperature rise of
1269 C (2316 F) exceeded any temperature rise that could be
achieved for the burning building. Therefore, in the severe case,
NFPA 80A uses a higher source temperature than EXPOSURE.

Figure 16 shows the maximum temperature rise based on Law's
expression [15] as the window area is varied. Note that NFPA 80A
does not allow for this effect. Also, Figure 17 shows the maximum
temperature rise as a function of building depth (or total fuel
load) for average fire loading of 10 and 50 lbs./sq. ft. Again
note that NFPA 80A does not take in account the effect of the
depth upon the maximum temperature rise.

The final source of disagreement arises from the determination of
the configuration factor. To minimize this an approach suggested
in NFPA 80A Appendix was used. Instead of applying a transparency
to the entire wall, the smallest rectangle that just encloses all
the openings was used. In the single opening case, this smallest
rectangle is just the window itself. If this approach is used to
determine the minimum separation, a minimum separation of 70.7
feet is obtained. This becomes 65.7 feet after removing the 5
feet safety margin. Then if EXPOSURE is forced to believe that
its source temperature is 1286 C, it gives a minimum separation
of 64.0 feet. This difference of 1.7 feet is insignificant. Thus
at this one point where both methods are in agreement as to the

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temperature of the source, configuration factor, and failure
mechanism there is reasonable agreement. The disagreements stem
from EXPOSURE using a more accurate determination of the
configuration factor, a more analytical estimation of the maximum
temperature, and a more accurate failure criteria.

E. Conclusions

EXPOSURE allows one to:

> 1. use an analytical expression (or expressions) for the
> temperature of the source,
> 2. use actual material properties such as the piloted
> ignition threshold, and
> 3. compute a more accurate configuration factor.

In the comparison of the results of the expert system EXPOSURE to
NFPA 80A significant differences are observed. In some cases
EXPOSURE calls for significantly greater separation and in others
significantly less.

As indicated above, EXPOSURE allows the use of an analytical
expression or expressions for the temperature of the source. It
is quite possible that additional expert opinion might not
support the use of the Law's equation that was used in this
program for the temperature of the source. Using expert system
programming techniques that allows the incorporation of heuristic
knowledge, a rule could be added to this program that would
specify under what conditions an equation should be used or when
another expression for the temperature of the source should be
used.

A second place where expert system programming techniques are of
great value is in obtaining a solution to an unsafe condition.
There are an infinity of possible ways of make the radiation
level falling on an exposed wall be in at an acceptable value.
The separation can be changed a little and something else can be
changed. To search for an optimal solution would involve a search
of an infinite set of possible solutions. Clearly this is not
feasible to do. The way to handle this is by using heuristics to
limit this search so an adequately good solution is found, not an
optimal one. In these two places the usefulness of using expert
system programming techniques are clearly demonstrated.

EXPOSURE allows the use of more appropriate technology, performs
more sophisticated analysis, and thereby obtains more accurate
results than those provided through the use of conventional fire
codes. The program can accommodate innovative materials by
allowing the use of the piloted ignition threshold of the

innovative material. It can also deal with innovative designs because the fire safety impact of such design features as the exact location of openings can be evaluated. Innovation could allow lower cost construction and greater safety. Also, compliance with a fire code like EXPOSURE will be much easier for the typical user.

Since EXPOSURE is not a completed program nor has it undergone extensive testing, its results must be used cautiously. However, EXPOSURE demonstrates that expert system fire codes can:
       a. make the technological base for fire codes stronger,
       b. reduce the arbitrariness in the applications of fire codes,
       c. reduce over and under design for safety, and
       d. make the process of applying or checking a building's compliance with fire codes more manageable.
Therefore, these results clearly indicate that significant cost-savings and improved safety can be realized by using expert system fire codes such as EXPOSURE.

F. Possible Future Work

This program could be further developed so that the advantages become much greater. Dropping any of the limiting assumptions listed for EXPOSURE would require additional development. Further items for future development of the program that hold promise of having significant impact include:

1. Expanding the graphic editor to allow such things as nonparallel walls.

2. Including flames outside the openings.

3. Including effects of weather such as wind.

4. Allowing nonpiloted ignition as a mechanism for igniting exposed targets inside the exposed building.

5. Adding a failure mode and solutions for noncombustible walls.

6. Incorporating piloted ignition data for construction materials.

Finally, in the future it also would be desirable to have the program compare the cost of protection to the value of what is being protected.

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MINIMUM SEPARATION (in ft.)

	NFPA 80A	EXPOSURE
Uniform Openings		
plain wood	60	44
covered wood	60	33
non-wood	60	24
One Opening		
plain wood	60	56
covered wood	60	47
non-wood	60	38

Table 1. Comparisons between NFPA 80A and EXPOSURE with Severe
Classification (50 lbs/sq. ft.) and Bldg-b 100' X 100'

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                MINIMUM SEPARATION (in ft.)

              NFPA 80A              EXPOSURE

Uniform Openings
     plain wood      60                 19
     covered wood    60                 15
     non-wood        60                 11
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Table 2. Comparisons between NFPA 80A and EXPOSURE with Severe
Classification (50 lbs/sq. ft.) and Bldg-b 10' X 100'

MINIMUM SEPARATION (in ft.)

	NFPA 80A	EXPOSURE
Uniform Openings plain wood	19	38
One Opening plain wood	19	51

Table 3. Comparisons between NFPA 80A and EXPOSURE with Light Classification (6.9 lbs/sq. ft.) and Bldg-b 100' X 100'
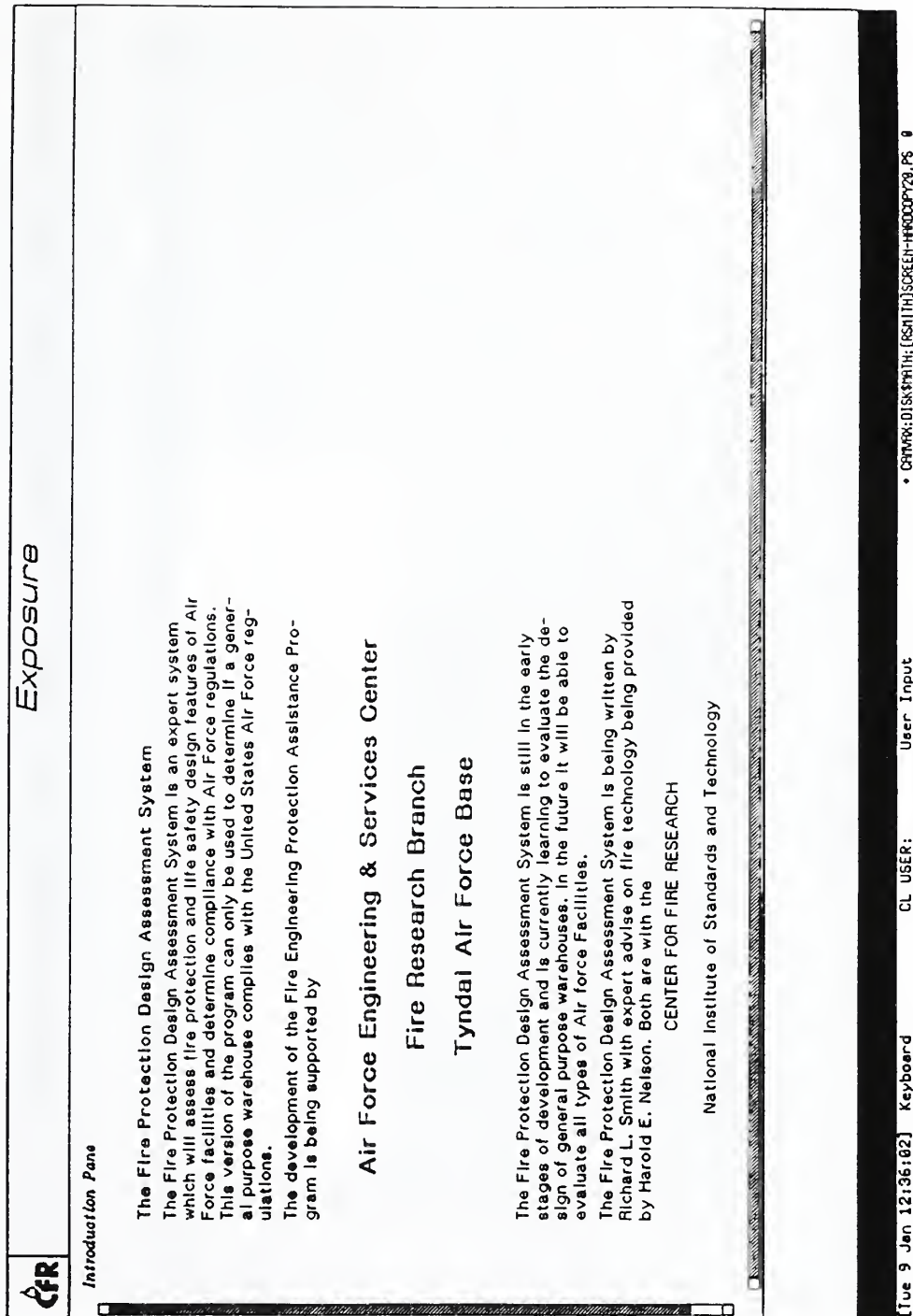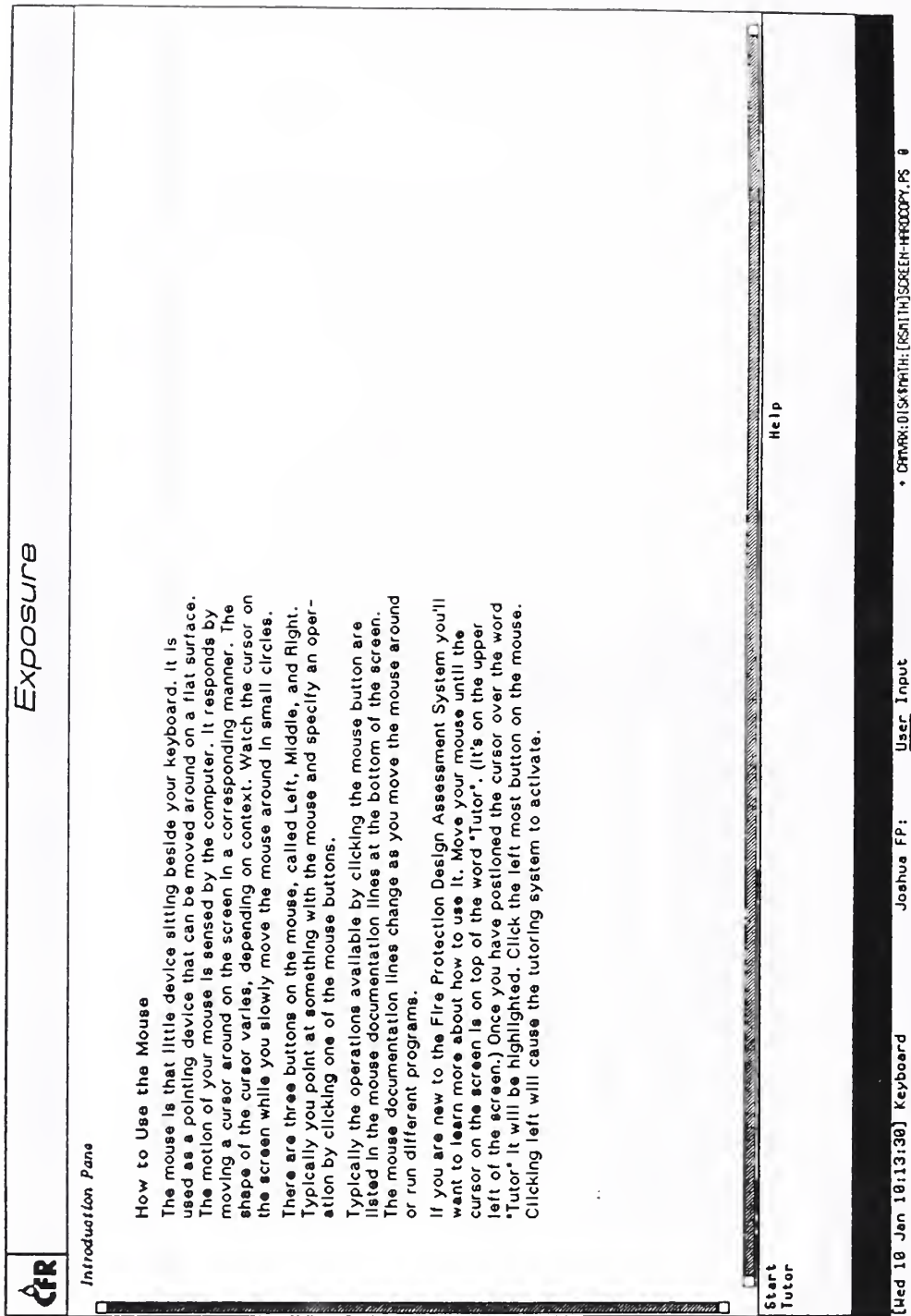
CFR

Introduction Pane

The Fire Protection Design Assessment System

The Fire Protection Design Assessment System is an expert system which will assess fire protection and life safety design features of Air Force facilities and determine compliance with Air Force regulations. This version of the program can only be used to determine if a general purpose warehouse complies with the United States Air Force regulations.

The development of the Fire Engineering Protection Assistance Program is being supported by

Air Force Engineering & Services Center

Fire Research Branch

Tyndal Air Force Base

The Fire Protection Design Assessment System is still in the early stages of development and is currently learning to evaluate the design of general purpose warehouses. In the future it will be able to evaluate all types of Air force Facilities.

The Fire Protection Design Assessment System is being written by Richard L. Smith with expert advise on fire technology being provided by Harold E. Nelson. Both are with the

CENTER FOR FIRE RESEARCH

National Institute of Standards and Technology

[Tue 9 Jan 12:36:02] Keyboard   CL USER: User Input   • CAYMAX:DISK$MITH:[RSMITH]SCREEN-HARDCOPY29.PS 0

Figure 1. Introduction Screen

19

CFR

Introduction Pane

How to Use the Mouse

The mouse is that little device sitting beside your keyboard. It is used as a pointing device that can be moved around on a flat surface. The motion of your mouse is sensed by the computer. It responds by moving a cursor around on the screen in a corresponding manner. The shape of the cursor varies, depending on context. Watch the cursor on the screen while you slowly move the mouse around in small circles.

There are three buttons on the mouse, called Left, Middle, and Right. Typically you point at something with the mouse and specify an operation by clicking one of the mouse buttons.

Typically the operations available by clicking the mouse button are listed in the mouse documentation lines at the bottom of the screen. The mouse documentation lines change as you move the mouse around or run different programs.

If you are new to the Fire Protection Design Assessment System you'll want to learn more about how to use it. Move your mouse until the cursor on the screen is on top of the word "Tutor". (It's on the upper left of the screen.) Once you have positioned the cursor over the word "Tutor" it will be highlighted. Click the left most button on the mouse. Clicking left will cause the tutoring system to activate.

Start Tutor

Help

[Wed 18 Jan 18:13:38] Keyboard   Joshua FP: User Input   • DRMAX:DISK$MATH:[RSMITH]SCREEN-HARDCOPY.PS 0

Figure 2. Instruction for Use of Mouse Screen

CFR

Introduction Pane

How to Use the Mouse

The mouse is that little device sitting beside your keyboard; it is
used as a pointing device that can be moved around on a flat surface.

Please type in your name :

Login Window

If you are new to the Fire Protection Design Assessment System you'll
want to learn more about how to use it. Move your mouse until the
cursor on the screen is on top of the word 'Tutor'. (It's on the upper
left of the screen.) Once you have positioned the cursor over the word
'Tutor' it will be highlighted. Click the left most button on the mouse.
Clicking left will cause the tutoring system to activate.

Start
Tutor

Help

Mouse-L: Select window; Mouse-R: System menu.

(Wed 10 Jan 10:15:27) Keyboard   Joshua FP;   User Input   • CHMRK:DISK$MAIN:[RSMITH]SCREEN-HARDCOPY.PS 0

Figure 3. Sign in Screen

21

Figure 4. Graphic Editor Screen

22

Exposure

CfR

PLAN: No Buffer   Units: 1 INCH = 50.0 FOOT

Pathname for plan

Pathname: S:>smith>exposure-analysis>version-1>center-window.lisp.newest

Done   Abort

Mouse-L: Select window; Mouse-R: System menu.

[Wed 17 Jan 12:51:20] Keyboard   Joshua FP: User Input

Extended Commands

• CANVAX:DISK:MATH:[RSMITH]SCREEN-HARDCOPY2.PS 0

Figure 5. Read Plan Menu
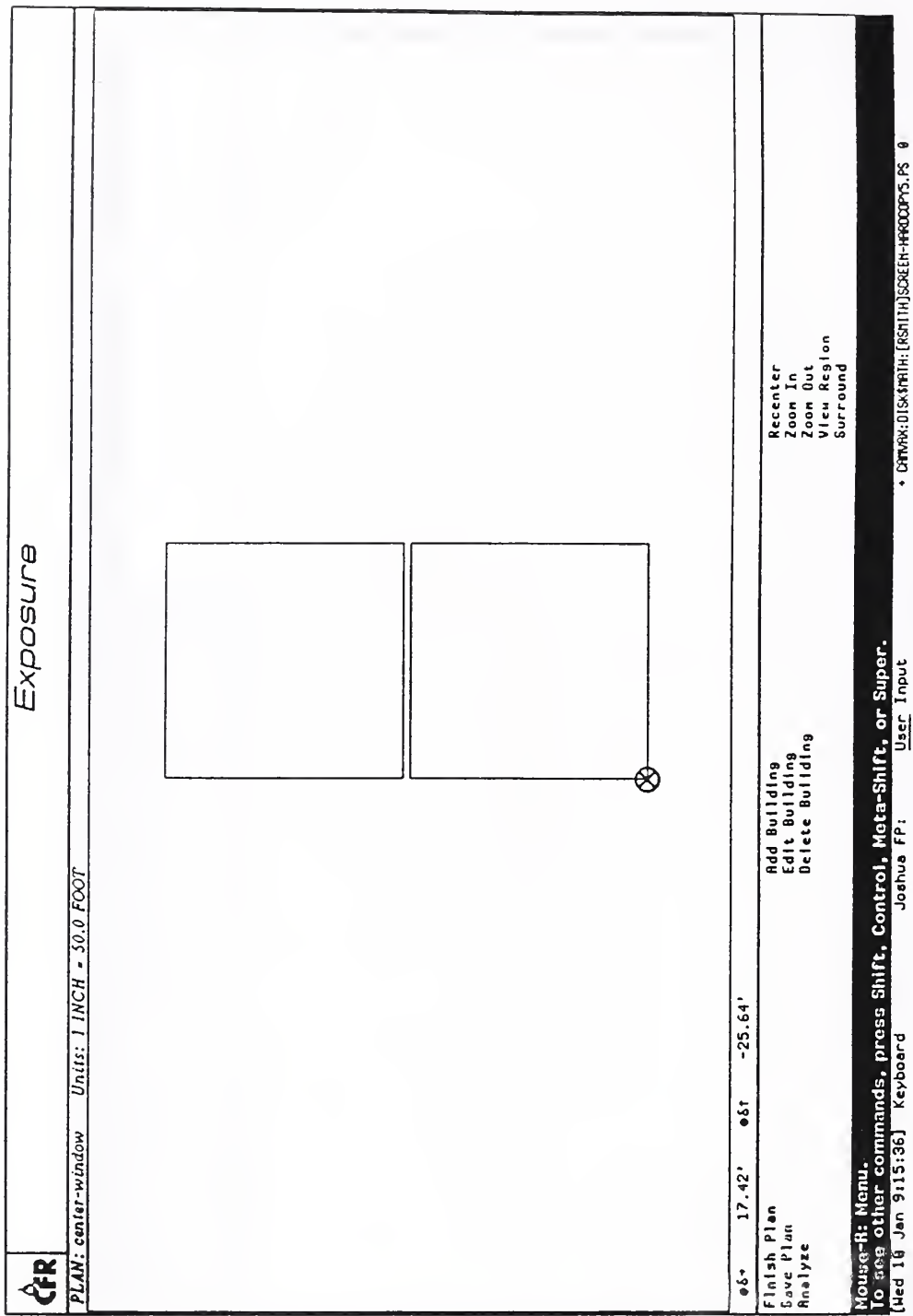
Figure 6. Top View of Two Buildings

Exposure

PLAN: center-window   Units: 1 INCH = 50.0 FOOT

Input new building

Building name: Unnamed building

Left: a number
Botton: a number
Width: a number
Height: a number

Height of walls: a number

(All numbers are in feet)

Left, Bottom: Undetermined
Right, Top: Undetermined

Done   Abort

⊗

●6+   -159.75'   ●6r   136.08'

Finish Plan   Add Building   Recenter
Save Plan   Edit Building   Zoom In
Analyze   Delete Building   Zoom Out
                                               View Region
                                               Surround

Mouse-R: Menu.
To see other commands, press Shift, Control, Meta-Shift, or Super.
(Wed 17 Jan 12:54:11) Keyboard   Joshua FP: User Input

• CAMAX:DISK$SMITH:[RSMITH]SCREEN-HARDCOPY.PS 0

Figure 7. Input New Building Menu

25
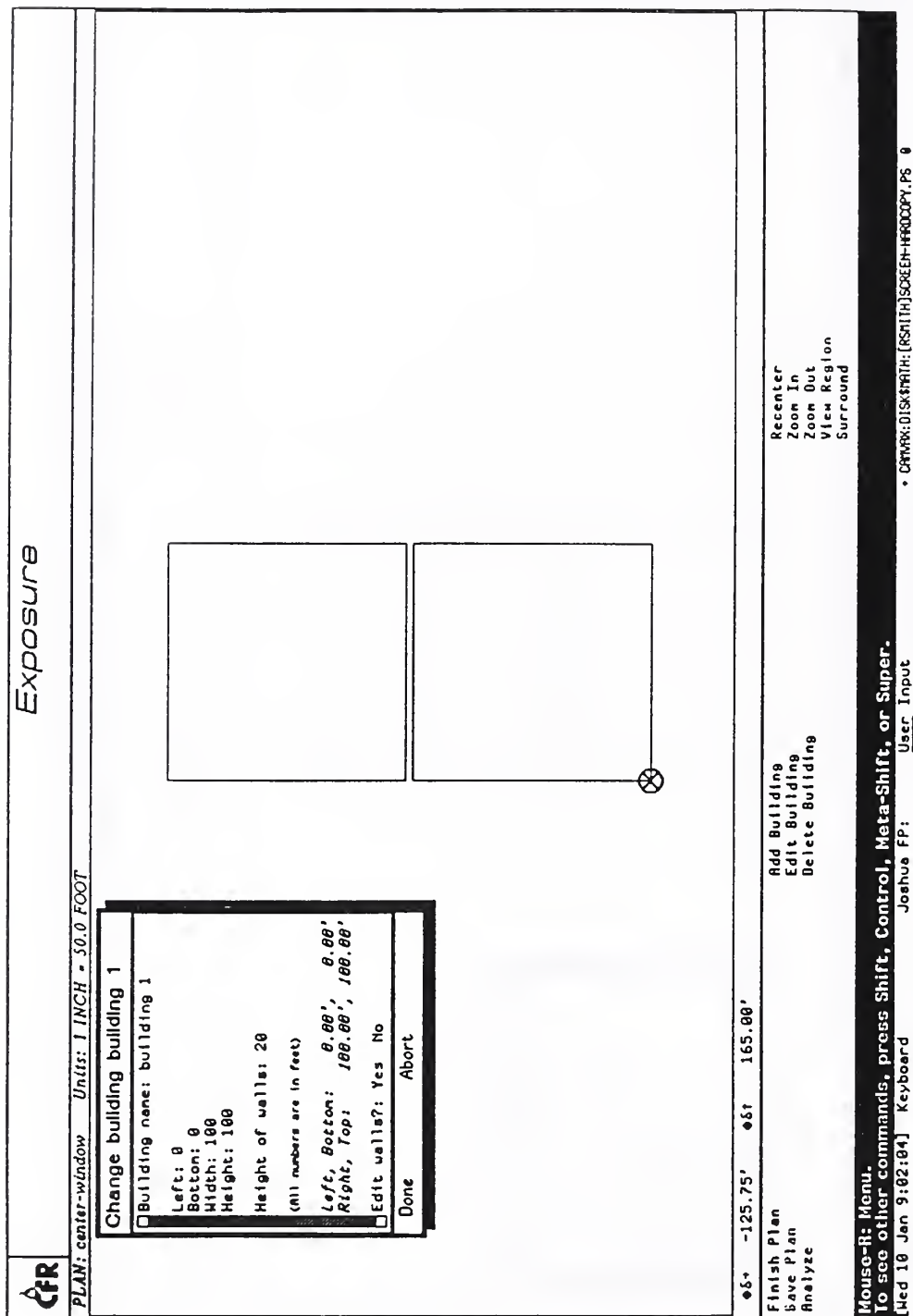
Figure 8. Edit Building Menu

26
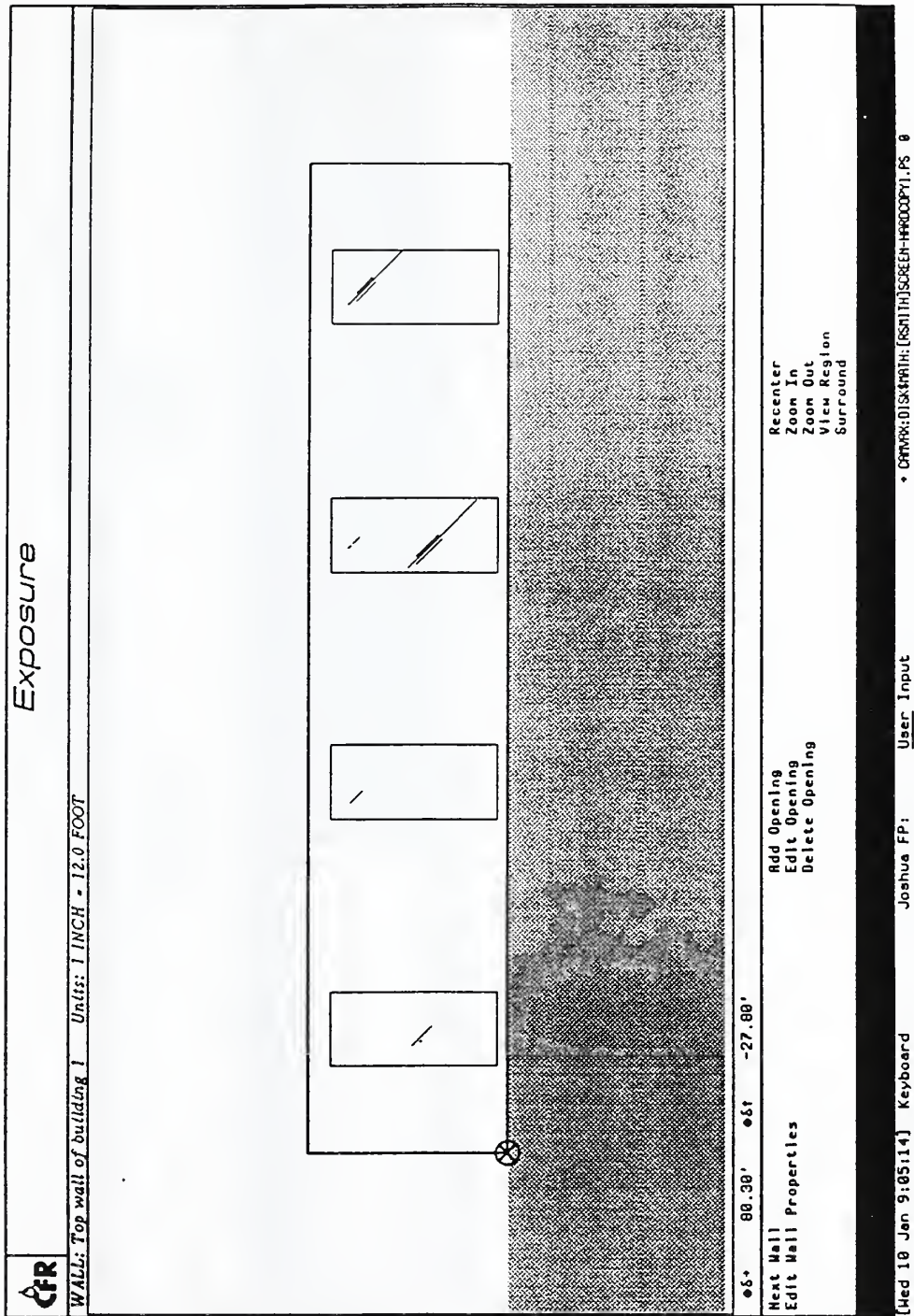
Figure 9. Elevation View of a Wall

27
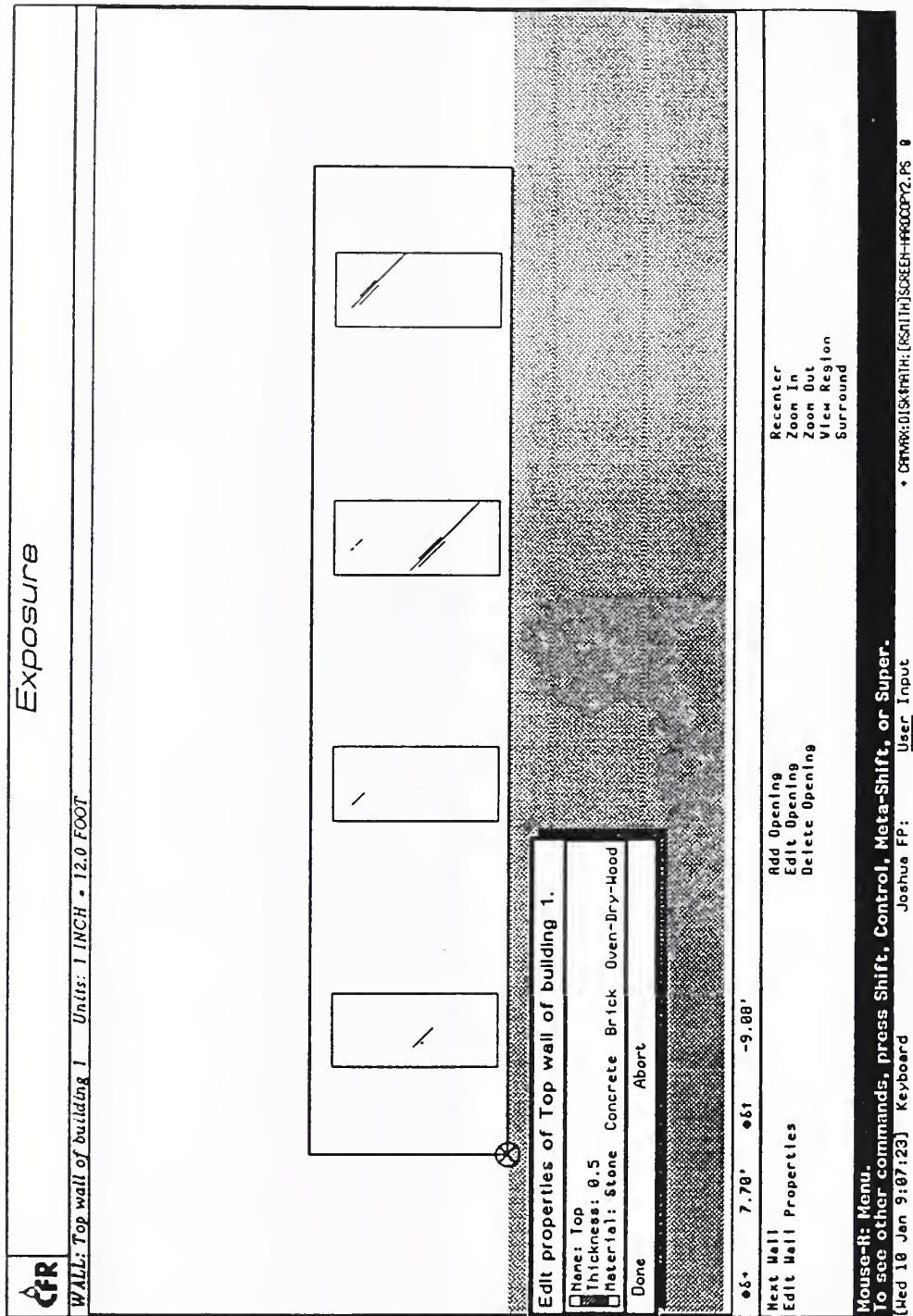
Figure 10. Wall Properties Menu
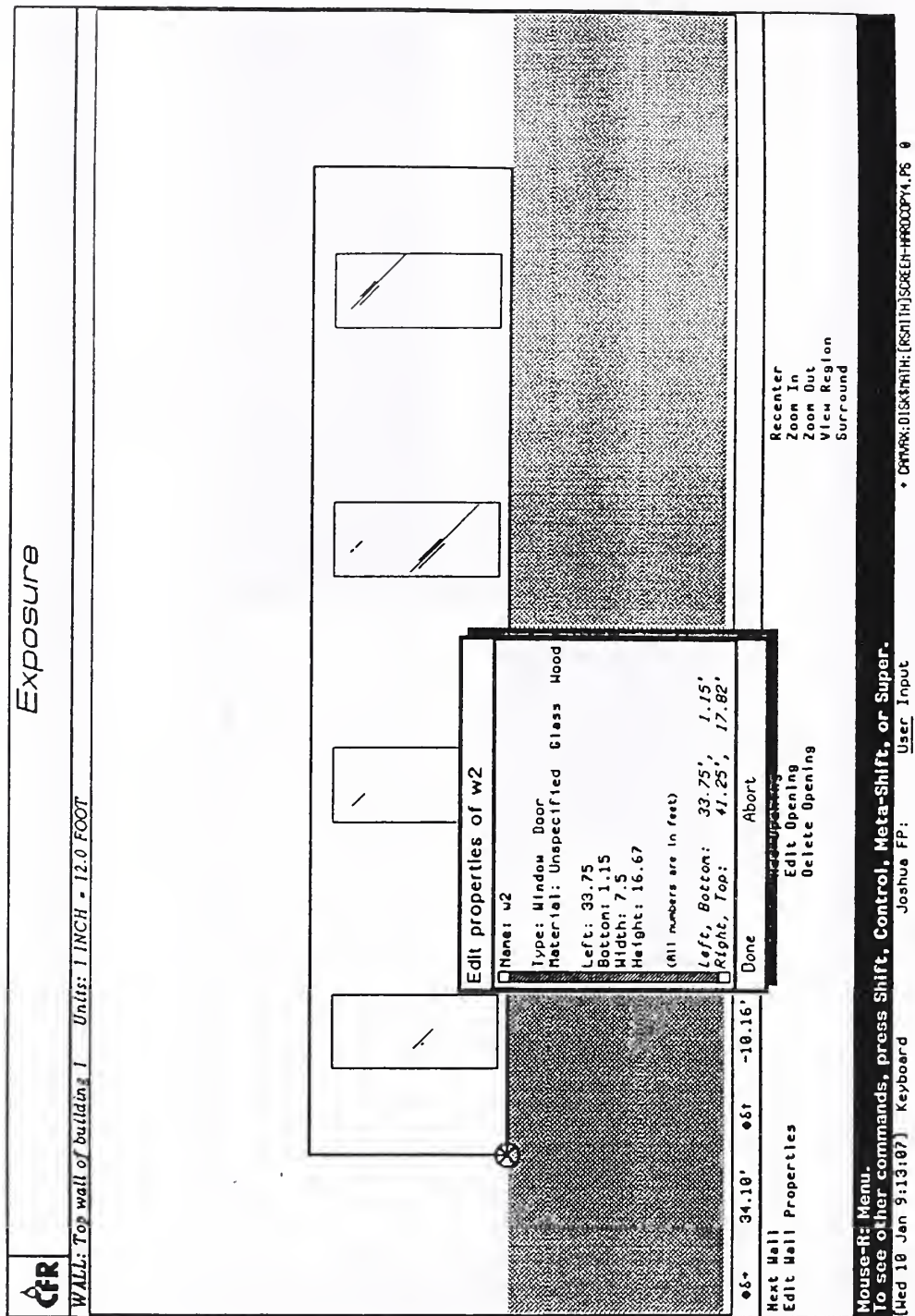
Figure 11. New Opening Menu

29

Figure 12. Menu for Editing Properties of an Opening

30

USAF/ESC   Exposure   developed by CFR/NIST

Clear Start Start Blank

Exposure Analysis command: Start
Exposure Analysis command: Clear
Exposure Analysis command:

Mouse-L, -R: Clear.
To see other commands, press Shift, Control, Meta-Shift, or Super.
[Wed 10 Jan 9:17:45] Keyboard   Joshua FP: User Input

• CRTRX:DISK&PATH:[RSMITH]SCREEN-HARDCOPY6.PS 0

Figure 13. Initial Screen for Analyzing Input

31

USAF/ESC	Exposure	developed by CFR/NIST

Clear Start Start Blank

(#<BUILDING 54044637> #<BUILDING 54053011>)

There is an exposure problem that must be corrected on building 2-Bottom.
The radiation falling on this wall exceeds the threshold by 0.14 watt/sq cm.

A possible solution to the exposure problem is to install an automatic
outside water curtain on building 2-Bottom at a cost of $ 100.

A possible solution to the exposure problem is to increase the SEPARATION
between building 1-Top and building 2-Bottom from 40 feet to 43.71
feet at a cost of $ 742.

A possible solution to the exposure problem is to change the wall MATERIAL
of building 2-Bottom from WOOD to   SIDING at a cost of $ 0.

Exposure Analysis command: Start
Exposure Analysis command: Start
Exposure Analysis command: Start
Exposure Analysis command:

Mouse-L, -R: Start.
To see other commands, press Shift, Control, Meta-Shift, or Super.
[Wed 17 Jan 2:48:56] Keyboard   Joshua FP: User Input

◆ CATWRK:DISKSMITH:[RSMITH]SCREEN-HARDCOPY1.PS 0

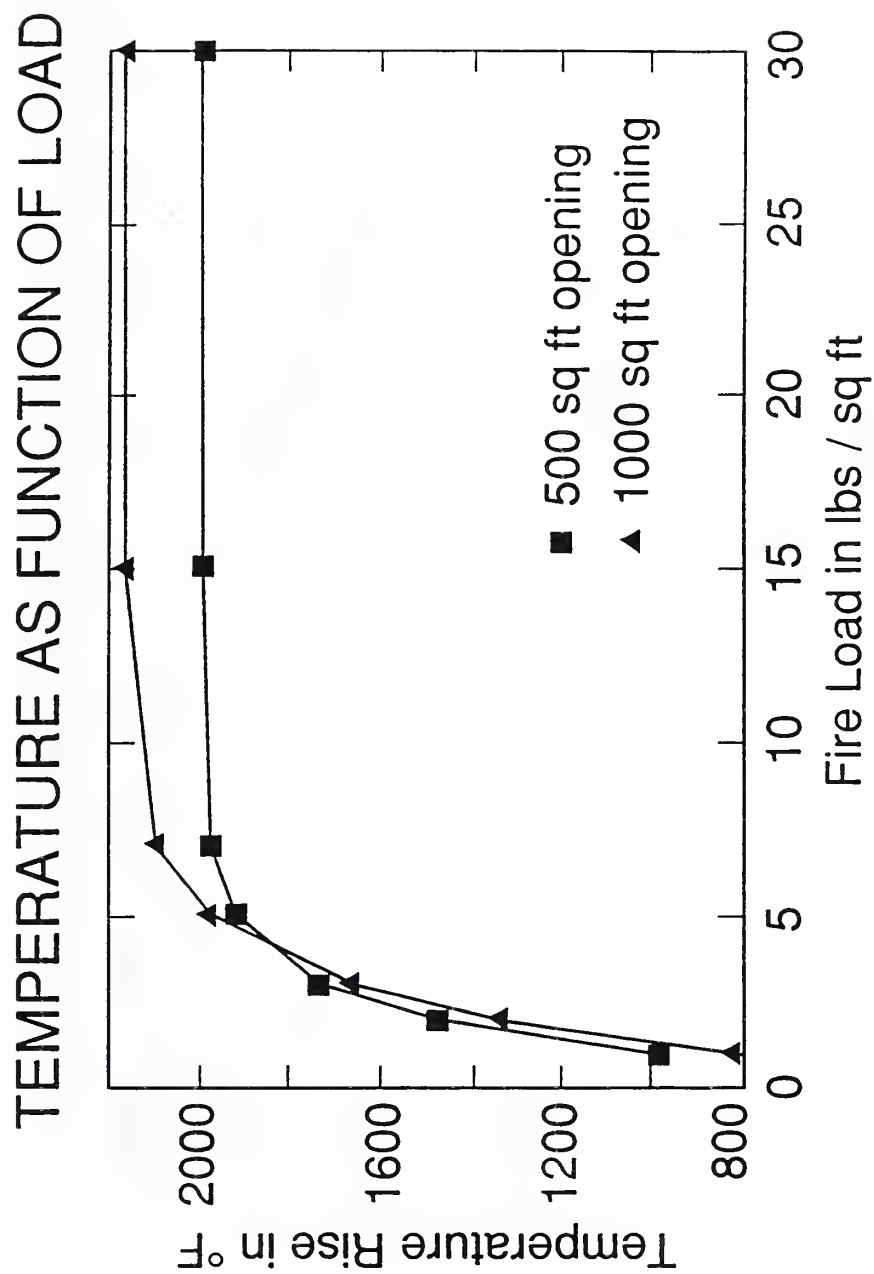Figure 14. EXPOSURE's Solutions to the Exposure Problem

32

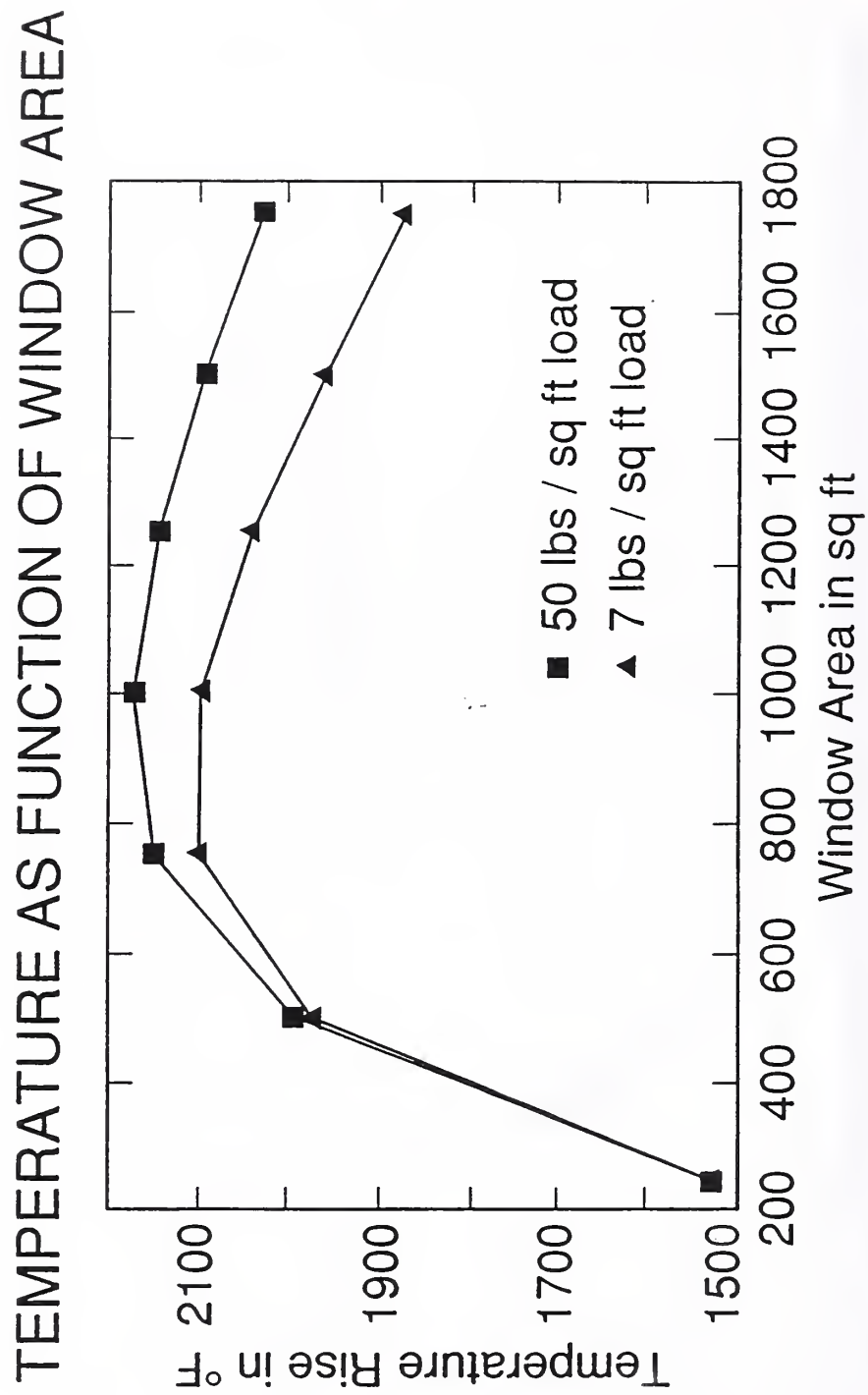Figure 15. Maximum Building Temperature Rise as a Function of
Fire Load

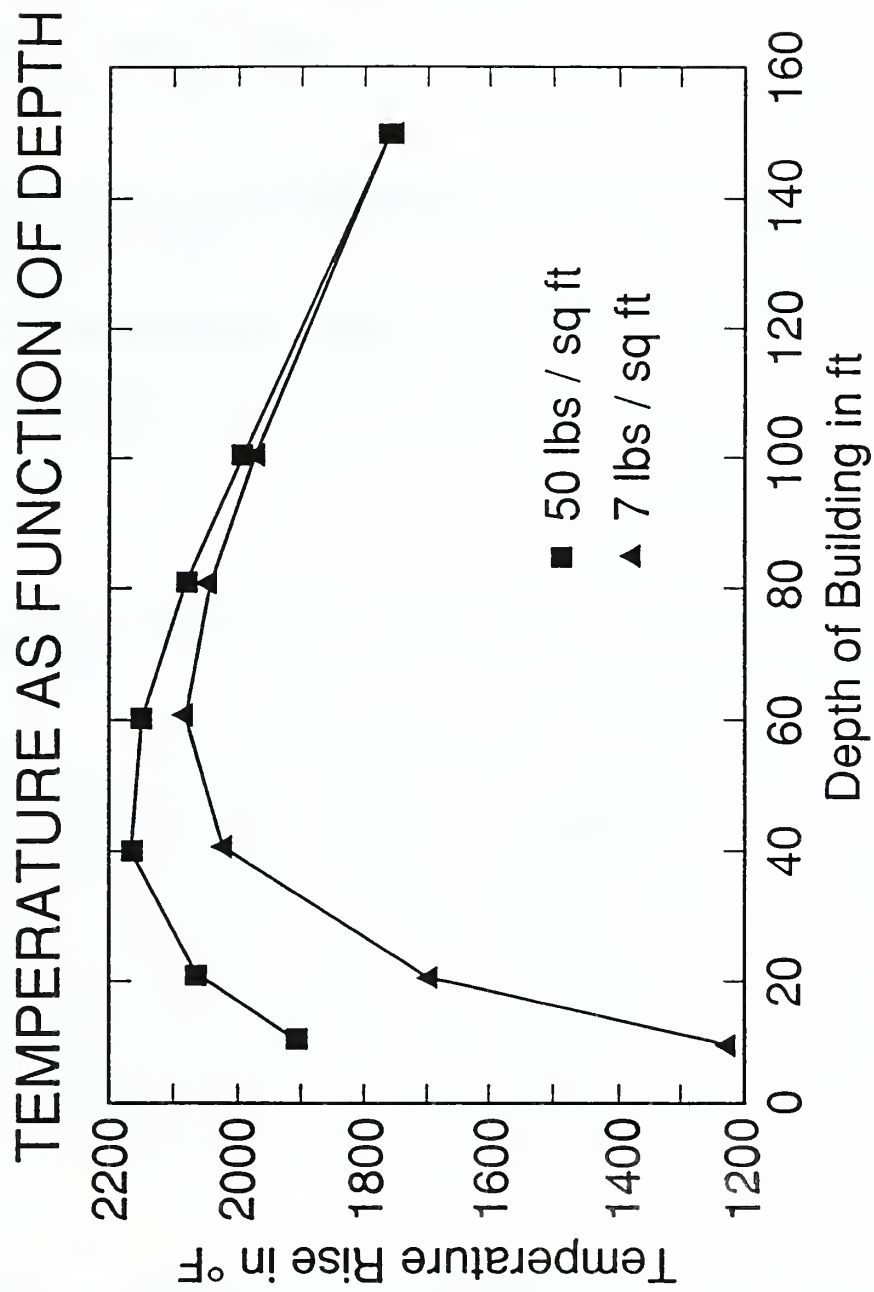Figure 16. Maximum Building Temperature Rise as a Function of
Window Area

Figure 17. Maximum Building Temperature Rise as a Function of
Building Depth

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Airbase Fire Protection and Crash Rescue System Branch
Tyndall AFB, FL 32403-6001

10. SUPPLEMENTARY NOTES

11. ABSTRACT (A 200-WORD OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, MENTION IT HERE.)

This report addresses the issue of developing an expert or knowledge-based system that deals with the problem of preventing the spread of fire between buildings. A knowledge-based program, EXPOSURE, has been developed that facilitates using more appropriate technology, expanding the problem domain, and providing cost-effective solutions. EXPOSURE can solve the problem of the prevention of the spread of fire between buildings for the case when the exposed building has combustible walls. The use of the expert system EXPOSURE and NFPA 80A produce significantly different recommended minimum separation between buildings. In some cases EXPOSURE calls for significantly greater separation and in others significantly less. In one case the separation required by NFPA 80A was more than five times greater than what EXPOSURE recommended. This program demonstrates that significant cost savings in achieving the desired level of fire safety and in assuring the levels of safety can be obtained by use of expert system fire codes.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)

artificial intelligence; building codes; computer programs; expert systems; exposure; fire codes

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